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SPACE AND TRANSATMOSPHERIC PROPULSION TECHNOLOGY

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SUMMARY

This report focuses primarily on Japan's programs in liquid rocket propulsion and propulsion for spaceplane and related transatmospheric areas. It refers briefly to Japan's solid rocket programs and to new supersonic air-breathing propulsion efforts.

Japan's long-term plans for space activity and its generic paths for achieving these plans were originally outlined in 1978 in the *Fundamental Policy of Japan's Space Development*. This document was revised in 1984 and 1989, and was expected to be updated periodically to keep Japan's policy consistent with advances in technology and changing socioeconomic factors. It shows Japan's space program to be a very aggressive and forward-looking one. This program emphasizes development of internal resources for various domestic and international space activities. Japan's domestic space interests encompass activities to exploit the unique environmental conditions of space, prepare for civil space development, and promote manned space activities. Plans for international collaborations include cooperating with programs established by other countries, initiating collaborative programs, and assisting developing countries.

Japan's space program is founded on two basic tenets: development of assured access to space and use of space activities solely for peaceful purposes. Work conducted by NASA with the U.S. Air Force might conflict with Japan's guideline concerning peaceful uses of space. However, there should be ample room for cooperative Japan-U.S. space endeavors. Japan's goals for the 1990s include plans for continuing its already strong thrust in scientific space research, bringing its

satellite and launch technologies up to international standards, creating the infrastructure for space station activities, and developing the basic technologies required for manned space activities.

Space transportation systems are of primary importance in Japan's near-term space plans. Near-term goals in space transportation are aimed at the development of an expendable launch system for transporting materials to geostationary orbit, technology for unmanned space-to-ground transportation, and fundamental R&D for long-term manned space transportation capabilities. Current transportation plans for expendable launch vehicles focus on developing and enhancing the H- and M-series of liquid and solid rocket systems.

GENERAL FINDINGS

Japan has several distinct space transportation efforts, including three expendable rocket launch vehicle programs and three air-breathing hypersonic vehicle concepts. The rocket launch vehicles include operational and developmental systems -- the N-series, the H-series, and the M-series. Air-breathing hypersonic vehicles were in the concept definition phase at the time of the panel's visit. The N-series of launch vehicles is based on U.S. technology developed under license. H-I vehicles include technology based in part on Japanese design and development and in part on licensed U.S. technology. The H-II vehicle, scheduled for first use in 1993, is completely Japanese in design, and positions Japan as a full-fledged member of the world launch community. The M-series rockets, solid boosters of Japanese design, are highly advanced and have proven capabilities for launching scientific satellites.

Japan's Tanegashima launch facilities are at nearly the same latitude as the U.S. facilities at Kennedy Space Center. The size of the launch site at Tanegashima is much smaller than that at Kennedy, and transportation facilities in the immediate area are somewhat limited. But these facilities appear to be adequate for the H-II. An agreement with local residents limits launch windows to a few weeks per year.

At the time of the panel's visit, engine development for Japan's space transportation efforts was divided into eight programs in stages ranging from concept development to operational: four cryogenic hydrogen-oxygen rocket engines and four advanced air-breathing systems. In conjunction with the H-series expendable launch vehicle program, the LE-5 cryogenic propulsion engine was operational, and propulsion development was under way for the LE-5a and the LE-7 cryogenic engines. Also under development were the HIPEX expander cycle engine, an additional new liquid hydrogen-oxygen engine; the liquid air cycle engine (LACE), a generic propulsion system oriented towards advanced air-breathing systems such as strap-on boosters for upgraded versions of the H-II; and the ATREX engine, an air turboramjet system. The remaining two propulsion systems were a scramjet engine concept intended for eventual hypersonic applications and a newly announced Mach 5 turbojet/turboramjet engine being developed for high-speed commercial transportation.

The panel found the systems and performance of Japan's cryogenic liquid rocket engines to be comparable to those of engines developed in the United States. The Japanese made extensive use of U.S. data, procedures, and technology in their designs; their engines also have similar specific impulse and vacuum thrust-to-weight ratios. However, the new engines are decidedly Japanese designs, showing a number of subtle but significant philosophical differences from U.S. systems. Japanese engine development programs were composed of carefully planned steps involving low-risk, well-characterized options. Japan's slightly more conservative design approach may facilitate reliability and be particularly beneficial if the engines or their derivatives are man-rated.

In the area of turbomachinery, Japanese turbopumps and turbines demonstrate performance levels similar to those of U.S. products. The Japanese are behind the United States in some areas of turbomachinery but ahead in others. In one instance they chose a two-stage over a three-stage pump to avoid a technology development program. Their cooperative efforts minimize duplication and maximize the rate of advancement.

By 1989, the Japanese were beginning a study of spaceplane concepts that emphasized such diverse topics as aerodynamics, structures, slush hydrogen fuel, Computational Fluid Dynamics (CFD), advanced propulsion, and system development scenarios. The propulsive cycles under study included the turbojet, the ramjet, the turboramjet, and the supersonic combustion ramjet (scramjet). The propulsion systems of primary interest appeared to be those for the Mach 3 to Mach 6 range for the low-Mach-number portion of hypersonic cruise or SSTO vehicles, strap-on booster augmentation engines for launch systems, or air-breathing engines for a civilian SST. Efforts in higher Mach number propulsion systems were directed more toward accumulating a database.

In engine development, the panel found two classes of engine in the prototype phase: the LACE engine at Mitsubishi Heavy Industries and the ATREX air turboramjet at Ishikawajima-Harima Heavy Industries. The LACE demonstrator engine used the LH2 pump and combustor from the LE-5 engine, along with new components for the air liquefier and the liquid air pump. The ATREX engine relied on existing turbojet-turbofan production and design experience and on the expander cycle technology developed in the HIPEX engine.

The Japanese program in scramjet applications was only in the concept definition phase when the JTEC panel visited. Scramjet technology programs included experimental studies of supersonic combustion, including ignition and diffusion flame studies, and shock tube studies of elementary reaction kinetics of hydrogen. High-speed inlet tests on a scale model were under way, as were university efforts in hypersonic reacting flows and component technology for advanced propulsion systems.

In advanced fuels development and on-plant construction for hydrogen production, Japan had two high-density hydrocarbon fuels for rocket applications, and was stepping up its hydrogen production capabilities to serve the H-II and advanced air-breathing propulsion systems. It was building a plant that made hydrogen as the by-product of ethylene production and a pilot facility to produce hydrogen from coal.

Japan was using the latest U.S. and European advanced diagnostics systems, but was leading in the development and manufacture of many of the basic lasers, optics, and electro-optic components for these systems. Tunable diode lasers and a surface-emitting diode laser with reduced beam divergence were developments in advanced diagnostics implementations that offered possibilities for improved spatial resolution.

CFD, important in all propulsion development, was seen to be an area of strength in Japan. Japanese supercomputers were acknowledged to be among the best in the world, and their availability had resulted in rapid progress in computational areas. The Japanese routinely included real gas effects and complex reaction kinetics in flow field analyses, and their codes were based on the latest algorithms. Their visualization and postprocessing capabilities were also at the leading edge. The Japanese had appropriate CFD capabilities to move rapidly in this aspect of propulsion development.

CONCLUSIONS

The panel observed that the Japanese had a carefully thought-out plan, a broad-based program, and an ambitious but achievable schedule for propulsion activity. Japan's overall propulsion program was behind that of the United States at the time of this study, but the Japanese were gaining rapidly. The Japanese are at the forefront in such key areas as advanced materials, enjoying a high level of project continuity and funding. Japan's space program has been evolutionary in nature, while the U.S. program has emphasized revolutionary advances. Projects have typically been smaller in Japan than in the United States, focusing on incremental advances in technology, with an excellent record of applying proven technology to new projects. This evolutionary approach, coupled with an ability to take technology off the shelf from other countries, has resulted in relatively low development costs, rapid progress, and enhanced reliability. Clearly Japan is positioned to be a world leader in space and transatmospheric propulsion technology by the year 2000.